AD NO.________________________
ATEC PROJECT NO. 2011-DT-ATC-DODSP-F0292
REPORT NO. ATC 11417

STANDARDIZED

UXO TECHNOLOGY DEMONSTRATION SITE

SCORING RECORD NO. 942

SITE LOCATION:
ABERDEEN PROVING GROUND

DEMONSTRATOR:
BATTELLE
100A DONNER DRIVE
OAK RIDGE, TN   37830

TECHNOLOGY TYPE/PLATFORM:
TEM-8G
TOWED ARRAY

AREAS COVERED:
BLIND GRID

PREPARED BY:
U.S. ARMY ABERDEEN TEST CENTER
ABERDEEN PROVING GROUND, MD   21005-5059

SEPTEMBER 2014

Prepared for:
SERDP/ESTCP
MUNITIONS MANAGEMENT
ARLINGTON, VA   22203

U.S. ARMY TEST AND EVALUATION COMMAND
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REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. REPORT DATE *(DD-MM-YYYY)*	2. REPORT TYPE	3. DATES COVERED *(From - To)*
September 2014	Final	November 2012

4. TITLE AND SUBTITLE
Standardized UXO Technology Demonstration Site
Scoring Record No. 942

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)

Lombardo, Leonard
Fling, Rick, Jr.
Hill, Scott

5d. PROJECT NUMBER
2011-DT-ATC-DODSP-F0292

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Commander
U.S. Army Aberdeen Test Center
ATTN: TEDT-AT-SLE
Aberdeen Proving Ground, MD 21005-5059

8. PERFORMING ORGANIZATION REPORT NUMBER
ATC-11417

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Program Manager
SERDP/ESTCP
Munitions Management
Arlington, VA 22203

10. SPONSOR/MONITOR'S ACRONYM(S)

11. SPONSOR/MONITOR'S REPORT NUMBER(S)
Same as Item 8

12. DISTRIBUTION/AVAILABILITY STATEMENT
Distribution unlimited, September 2014.

13. SUPPLEMENTARY NOTES
None

14. ABSTRACT

This scoring record documents the efforts of the Environmental Security Technology Certification Program (ESTCP) to detect and discriminate inert unexploded ordnance (UXO) using the U.S. Army Aberdeen Proving Ground (APG) Standardized UXO Technology Demonstration Site calibration lanes and open field sites. This Scoring Record was coordinated by J. Stephen McClung and the Standardized UXO Technology Demonstration Site Scoring Committee. Organizations on the committee include the U.S. Army Corps of Engineers, the ESTCP, the Strategic Environmental Research and Development Program (SERDP), the Institute for Defense Analysis (IDA), the U.S. Army Environmental Command (USAEC), and the U.S. Army Aberdeen Test Center (ATC).

15. SUBJECT TERMS
Environmental Security Technology Certification Program, APG, Standardized UXO Technology Demonstration Site, blind grid, towed array.

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			Leonard Lombardo
U	U	U	SAR	62	19b. TELEPHONE NUMBER *(Include area code)* 410-278-1286

ACKNOWLEDGMENTS

Authors:

Leonard Lombardo
Threat Detection and Systems Survivability (TDSS)
U.S. Army Aberdeen Test Center (ATC)
Aberdeen Proving Ground (APG)

Rick Fling
Aberdeen Test Support Services (ATSS)
Sverdrup Technology, Inc.
Aberdeen Proving Ground

Contributors:

Scott Hill
Threat Detection and Systems Survivability
U.S. Army Aberdeen Test Center
Aberdeen Proving Ground

Christina McClung
Survivability and Lethality (SL) Directorate
U.S. Army Aberdeen Test Center
Aberdeen Proving Ground

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SECTION 1. GENERAL INFORMATION

1.1 BACKGROUND

Technologies under development for the detection and discrimination of unexploded ordnance (UXO) require testing so that their performance can be characterized. To that end, Standardized Test Sites have been developed at the U.S. Army Aberdeen Proving Ground (APG), Maryland, and the U.S. Army Yuma Proving Ground (YPG), Arizona. These test sites provide a diversity of geology, climate, terrain, and weather as well as diversity in ordnance and clutter. Testing at these sites is independently administered and analyzed by the Government for the purposes of characterizing technologies, tracking performance with system development, comparing performance of different systems, and comparing performance in different environments (app E, ref 1).

The Standardized UXO Technology Demonstration Site Program is a multiagency program spearheaded and funded by the Environmental Securities Technology Certification Program (ESTCP), the Strategic Environmental Research and Development Program (SERDP). The U.S. Army Aberdeen Test Center (ATC) provides programmatic and field support for technology demonstration and evaluation and maintains a repository of inert munition items available to the UXO community. The U.S. Army Environmental Command (USAEC) maintains the Standardized UXO Technology Demonstration Site Program web page (http://aec.army.mil/usaec/technology/uxo01.html), which contains program information, vendor demonstration instructions, and copies of all published vendor demonstration scoring records.

1.2 SCORING OBJECTIVES

The objective in the Standardized UXO Technology Demonstration Site Program is to evaluate the detection and discrimination capabilities of a given technology under various field and soil conditions. Inert munitions and clutter items are positioned in various orientations and depths in the ground.

The evaluation objectives are as follows:

a. To determine detection and discrimination effectiveness under realistic scenarios with various targets, geology, clutter, density, topography, and vegetation.

b. To determine cost, time, and workforce requirements to operate the technology.

c. To determine the demonstrator’s ability to analyze survey data in a timely manner and provide prioritized Target Lists with associated confidence levels.

d. To provide independent site management to enable the collection of high quality, ground truth (GT), geo-referenced data for post-demonstration analysis.

1.2.1 Scoring Methodology

a. The scoring of the demonstrator's performance is conducted in two stages: response stage and discrimination stage. For both stages, the probability of detection (P_d) and the false alarms are reported as receiver-operating characteristic (ROC) curves. False alarms are divided into those anomalies that correspond to emplaced clutter items, measuring the probability of clutter detection (P_{cd}) or the probability of false positive (P_{fp}). Those that do not correspond to any known item are termed background alarms. The background alarms are addressed as either probability of background alarm (P_{ba}) or background alarm rate (BAR).

b. The response stage scoring evaluates the ability of the system to detect emplaced targets without regard to ability to discriminate munitions from other anomaly sources. For the blind grid response stage, the demonstrator provides a target response from each and every grid square along with a threshold below which target responses are deemed insufficient to warrant further investigation. This list is generated with minimal processing and, since a value is provided for every grid square, includes amplitudes both above and below the system noise level. For the open field, the demonstrator provides a list of all anomalies deemed to exceed a demonstrator selected target detection threshold. An item (either munition or clutter) is counted as detected if a demonstrator indicates an anomaly within a specified distance (halo radius (R_{halo})) of a GT item.

c. The discrimination stage evaluates the demonstrator's ability to correctly identify munitions as such and to reject clutter. For the blind grid discrimination stage, the demonstrator provides the output of the discrimination stage processing for each grid square. For the open field, the demonstrator provides the output of the discrimination stage processing for anomaly reported in the response stage. The values in these lists are prioritized based on the demonstrator's determination that a location is likely to contain munitions. Thus, higher output values are indicative of higher confidence that a munitions item is present at the specified location. For digital signal processing, priority ranking is based on algorithm output. For other discrimination approaches, priority ranking may be based on rule sets or human judgment. The demonstrator also specifies the threshold in the prioritized ranking that provides optimum performance, (i.e., that is expected to retain all detected munitions and reject the maximum amount of clutter).

d. The demonstrator is also scored on efficiency and rejection ratios, which measure the effectiveness of the discrimination stage processing. The goal of discrimination is to retain the greatest number of munitions detections from the anomaly list while rejecting the maximum number of anomalies arising from nonmunitions items. Efficiency measures the fraction of detected munitions retained after discrimination, and the rejection ratio measures the fraction of false alarms rejected. Both measures are defined relative to the maximum number of munitions detectable by the sensor and its accompanying clutter detection/false positive rate or BAR.

e. Based on configuration of the GT at the standardized sites and the defined scoring methodology, in some cases, there exists the possibility of having anomalies within overlapping halos and/or multiple anomalies within halos. In these cases, the following scoring logic is implemented:

(1) In situations where multiple anomalies exist within a single R_{halo}, the anomaly with the strongest response or highest ranking will be assigned to that particular GT item. If the responses or rankings are equal, then the anomaly closest to the GT item will be assigned to the GT item. Remaining anomalies are retained and scored until all matching is complete.

(2) Anomalies located within any R_{halo} that do not get associated with a particular GT item are excess alarms and will be disregarded.

f. In some cases, groups of closely spaced munitions have overlapping halos. The following scoring logic is implemented (app A, fig. A-1 through A-9):

(1) Overall site scores (i.e., P_d) will consider only isolated munitions and clutter items.

(2) GT items that have overlapping halos (both munitions and clutter) will form a group and groups may form chains.

(3) Groups will have a complex halos composed of the composite halos of all its GT items.

(4) Groups will have three scoring factors: groups found, groups identified, and group coverage. Scores will be based on 1:1 matches of anomalies and GT.

(a) Groups Found (Found): The number of groups that have one or more GT items matched divided by the total number of groups. Demonstrators will be credited with detecting a group if any item within the group is matched to an anomaly in their lists.

(b) Groups Identified (ID): The number of groups that have two or more GT items matched divided by the total number of groups. Demonstrators will be credited with identifying that a group is present if multiple items within the composite halo are matched to anomalies in their lists.

(c) Group Coverage (Coverage): The number of GT items matched within groups divided by the total number of GT items within groups. This metric measures the demonstrator accuracy in determining the number of anomalies within a group. If five items are present and only two anomalies are matched, the demonstrator will score 0.4. If all five are matched, the demonstrator will score 1.0.

(5) Location error will not be reported for groups.

(6) Demonstrators will not be asked to call out groups in their scoring submissions. If multiple anomalies are indicated in a small area, the demonstrator will report all individual anomalies.

(7) Excess alarms within a halo will be disregarded.

g. All scoring factors are generated using the Standardized UXO Probability and Plot Program, version 4.

1.2.2 Scoring Factors

Factors measured and evaluated as part of this demonstration include:

a. Response stage ROC curves:

(1) Probability of detection (P_d^{res}).

(2) Probability of clutter detection (P_{cd}).

(3) Background alarm rate (BAR^{res}) or probability of background alarm (P_{ba}^{res}).

b. Discrimination stage ROC curves:

(1) Probability of detection (P_d^{disc}).

(2) Probability of false positive (P_{fp}).

(3) Background alarm rate (BAR^{disc}) or probability of background alarm (P_{ba}^{disc}).

c. Metrics:

(1) Efficiency (E).

(2) False positive rejection rate (R_{fp}).

(3) Background alarm rejection rate (R_{ba}).

d. Other:

(1) Probability of detection by size, depth, and density.

(2) Classification by type (i.e., 20-, 40-, 105-mm, etc.).

(3) Location accuracy for single munitions.

(4) Equipment setup, calibration time, and corresponding worker-hour requirements.

(5) Survey time and corresponding worker-hour requirements.

(6) Reacquisition/resurvey time and worker-hour requirements (if any).

(7) Downtime due to system malfunctions and maintenance requirements.

SECTION 2. DEMONSTRATION

2.1 DEMONSTRATOR INFORMATION

2.1.1 Demonstrator Point of Contact (POC) and Address

POC:Jeff Gamey
Address:100A Donner Dr., Oak Ridge, TN 37830

2.1.2 System Description (provided by demonstrator)

The TEM-8G is a time-domain electromagnetic array consisting of a single Z-axis transmitter and eight Z-axis receivers, towed on a wheeled or skid-mounted platform behind a utility vehicle. Navigation is visual for small areas (all APG sites). Data positioning uses a dual Digital Global Positioning System (DGPS) with post-processing to determine location and orientation.

The transmitter uses an alternating castle waveform with a 30 Hz base frequency and a 50% duty cycle. The transmitter frame is 2 m by 0.75 m with 12 turns of wire carrying 60 A of current and producing a peak magnetic moment of 1080 Am^2. The receivers are 0.2 m diameter circles spaced at 0.22 m intervals in a line across the middle of the transmitter. Sensor height is variable and positioned as low as possible to the ground. Nominal sensor height is 15 to 25cm.

Data are recorded at 30 Hz for seven geometrically spaced time-gates between 0.4 and 8 ms. At a forward speed of approximately 2 m/s, this represents a down-line data spacing of 0.07 m. A single-pass swath covers 1.8 m. A line spacing of 1.5 m (or 5 ft.) is used to ensure complete coverage of the site.

Figure 1. TEM-8G/towed array.

2.1.3 Data Processing Description (provided by demonstrator)

The section should be submitted for each area surveyed by the vendor. Discussion should include how target selection, parameter estimation, and classification vary by site area and objective. The following information should be submitted to ATC within 30 days before each area is surveyed:

Target selection criteria: This section will detail the target selection criteria and the data required to implement the criteria by answering the following questions:

a. What kind of pre-processing (if any) is applied to the raw data (e.g. filtering, etc)?

Minimal low-pass filter.

b. What is the format of the data both pre and post processing of the raw data (e.g. ASCII, binary, etc)?

Recorded as binary, converted to ASCII and imported to Geosoft GDB.

c. What algorithm is used for detection (e.g. peaks of signal surpassing threshold, etc)?

Peakedness, with proximate anomalies combined to a single target.

d. Why is this algorithm used and not others?

Past experience has shown this to be a reliable method.

e. On what principles are the algorithm based (e.g. statistical models, heuristic rules, etc)?

Tests each grid point relative to those immediately adjacent to it and outwards in increasing circles to find reliable peak locations.

f. What tunable parameters (if any) are used in the detection process (e.g. threshold on signal amplitude, window length, filter coefficients, etc)?

The number of circles of data tested, and the number of points in each ring which the center value must be larger than can be adjusted.

g. What are the final values of all tunable parameters for the detection algorithm?

This will be determined by analysis of the Calibration Grid data.

Parameter estimation: This section should include the details of which parameters will be extracted from the sensor data for each detected item for characterization. Please answer the following questions:

a. Which characteristics will be extracted from each detected item and input to the discrimination algorithm (e.g. depth, size, polarizability coefficients, fit quality, etc.)?

Output parameters include target location, depth, inversion fit quality and polarizability decays.

b. Why have these characteristics been chosen and not others (e.g. empirical evidence of their ability to help discriminate, inclusion in a theoretical tradition, etc.)?

These parameters are the industry standard for ordnance classification.

c. How are these characteristics estimated (e.g. least-mean-squares fit to a dipole model, etc.), include the equations that are used for parameter estimation?

They are estimated from a least squares fit to a dipole model.

d. What tunable parameters (if any) are used in the characterization process? (e.g. thresholds on background noise, etc)?

The number of dipoles and the background zero levels can be adjusted to improve inversion results.

Classification: This section should include the details describing the algorithm and associated data and parameters used for discrimination by answering the following questions:

a. What algorithm is used for discrimination (e.g. multi-layer perception, support vector machine, etc.)?

A rules-based classification system has been derived from training data sets.

b. Why is this algorithm used and not others?

This system has proven reliable on other calibration targets.

c. Which parameters are considered as possible inputs to the algorithm?

The amplitude of the primary polarizability, the amplitude of the secondary polarizability, and the decay of the primary polarizability are the three input parameters. These represent a three-dimensional parameter space for classification. Measured results are compared to a library of target types. If the measured results are close enough to the average library values then an ordnance declaration is made.

d. What are the outputs of the algorithm (probabilities, confidence levels)?

The output is a dig list divided into four basic categories: TOI, non-TOI, cannot decide, cannot analyze.

e. How is the threshold set to decide where the munitions/non-munitions line lies in the discrimination process?

Thresholds are set based on the standard deviation of the training sets.

Training: This section should include the details of how training data is used to make a decision on the likelihood of the anomaly correspondence to munitions. Please answer the following questions:

a. Which tunable parameters have final values that are optimized over a training set of data and which have values that are set according to geophysical knowledge (i.e. intuition, experience, common sense)?

The average library values for each target are based on a measured training set. The thresholds, in terms of the number of standard deviations within which to make a declaration, are based on a combination of the training data and experience with the measured values from a particular site.

(1) For those tunable parameters with final values set according to geophysical knowledge:

(a) What is the reasoning behind choosing these particular values?

(b) Why were the final values not optimized over a training set of data?

This is a new system and the size of the training set is still too small.

(2) For those tunable parameters with final values optimized over the training set data:

(a) What training data is used (e.g. all data, a randomly chosen portion of data, etc)?

All targets from the Calibration Grid are used.

(b) What error metric is minimized during training (e.g. mean squared error, etc)?

Results are averaged and standard deviation calculated.

(c) What learning rule is used during training (e.g. gradient descent, etc)?

Not applicable (NA).

(d) What criterion is used to stop training (e.g. number of iterations exceeds threshold, good generalization over validation set of data, etc.)?

NA.

(e) Are all tunable parameters optimized at once or in sequence ("in sequence" = parameters 1 is held constant at some common sense values while parameter 2 is optimized, and then parameter 2 is held constant at its optimized value while parameter 1 is optimized)?

NA

b. What are the final values of all tunable parameters for the characterization process?

2.1.4 Data Submission Format

Data were submitted for scoring in accordance with data submission protocols outlined on the USAEC Website (www.uxotestsites.org). These submitted data are not included in this report to protect GT information.

2.1.5 Demonstrator Quality Assurance (QA) and Quality Control (QC) (provided by demonstrator)

NA

2.1.6 Additional Records

The following record(s) by this vendor can be accessed via the Internet as Microsoft Word documents at www.uxotestsites.org.

2.2 U.S. ARMY ABERDEEN PROVING GROUND (APG) SITE INFORMATION

2.2.1 Location

The APG Standardized Test Site is located within a secured range area of the Aberdeen Area. The Aberdeen Area of APG is located approximately 30 mi northeast of Baltimore at the northern end of the Chesapeake Bay. The Standardized Test Site encompasses 17 acres of upland and lowland flats, woods, and wetlands.

2.2.2 Soil Type

According to the soils survey conducted for the entire area of APG in 1998, the test site consists primarily of Elkton Series type soil (ref 2). The Elkton Series consist of very deep, slowly permeable, poorly drained soils. These soils formed in silty aeolin sediments and the underlying loamy alluvial and marine sediments. They are on upland and lowland flats and in depressions of the Mid-Atlantic Coastal Plain. Slopes range from 0 to 2 percent.

The U.S. Army Corps of Engineers Research and Development Center (ERDC) conducted a site-specific analysis in May 2002 (ref 3). The results matched the soil survey mentioned above. Seventy percent of the samples taken were classified as silty loam. The majority (77 percent) of the soil samples had a measured water content between 15 and 30 percent with the water content decreasing slightly with depth.

For more details concerning the soil properties at the APG test site, go to www.uxotestsites.org to view the entire soils description report.

2.2.3 Test Areas

A description of the test site areas at APG is provided in Table 1. A test site layout is shown in Figure 2.

TABLE 1. TEST SITE AREAS

Area	Description
Calibration lanes	Contains 14 standard munitions items buried in six positions, with representation of clutter, at various angles and depths to allow demonstrators to calibrate their equipment.
Blind grid	Contains 400 grid cells in a 0.5-acre site. The center of each grid cell contains either munitions, clutter, or nothing.
Open field	A 10-acre site composed of generally open and flat terrain with minimal clutter and minor navigational obstacles. Vegetation height varies from 15 to 25 cm. This area is subdivided into four subareas (legacy, direct fire, indirect fire, and challenge).
	•*Open field (legacy)* The legacy subarea contains the same wide variety of randomly-placed munitions that were present in the open field prior to the January 2008 general reconfiguration of the site.
	•*Open field (direct fire)* The direct fire subarea contains only three munition types that could be typically found at an impact area of a direct fire weapons range. Munitions and clutter are placed in a pattern typical for these munitions.
	•*Open field (indirect fire)* The indirect fire subarea contains only three munition types that could be typically found at an impact area of an indirect fire weapons range. Munitions and clutter are placed in a pattern typical for these munitions.
	•*Open field (challenge)* The challenge subarea is easily reconfigurable to meet the specific needs and requirements of the demonstrator or the program sponsor. Any results from this area are not reported in the standardized scoring record.
Woods	1.34-acre area consisting of cleared woods (tree removal with only stumps remaining), partially cleared woods (including all underbrush and fallen trees), and virgin woods (i.e., woods in natural state with all trees, underbrush, and fallen trees left in place).
Moguls	1.30-acre area consisting of two areas (the rectangular or driving portion of the course and the triangular section with more difficult, nondrivable terrain). A series of craters (as deep as 0.91 m) and mounds (as high as 0.91 m) encompass this section.

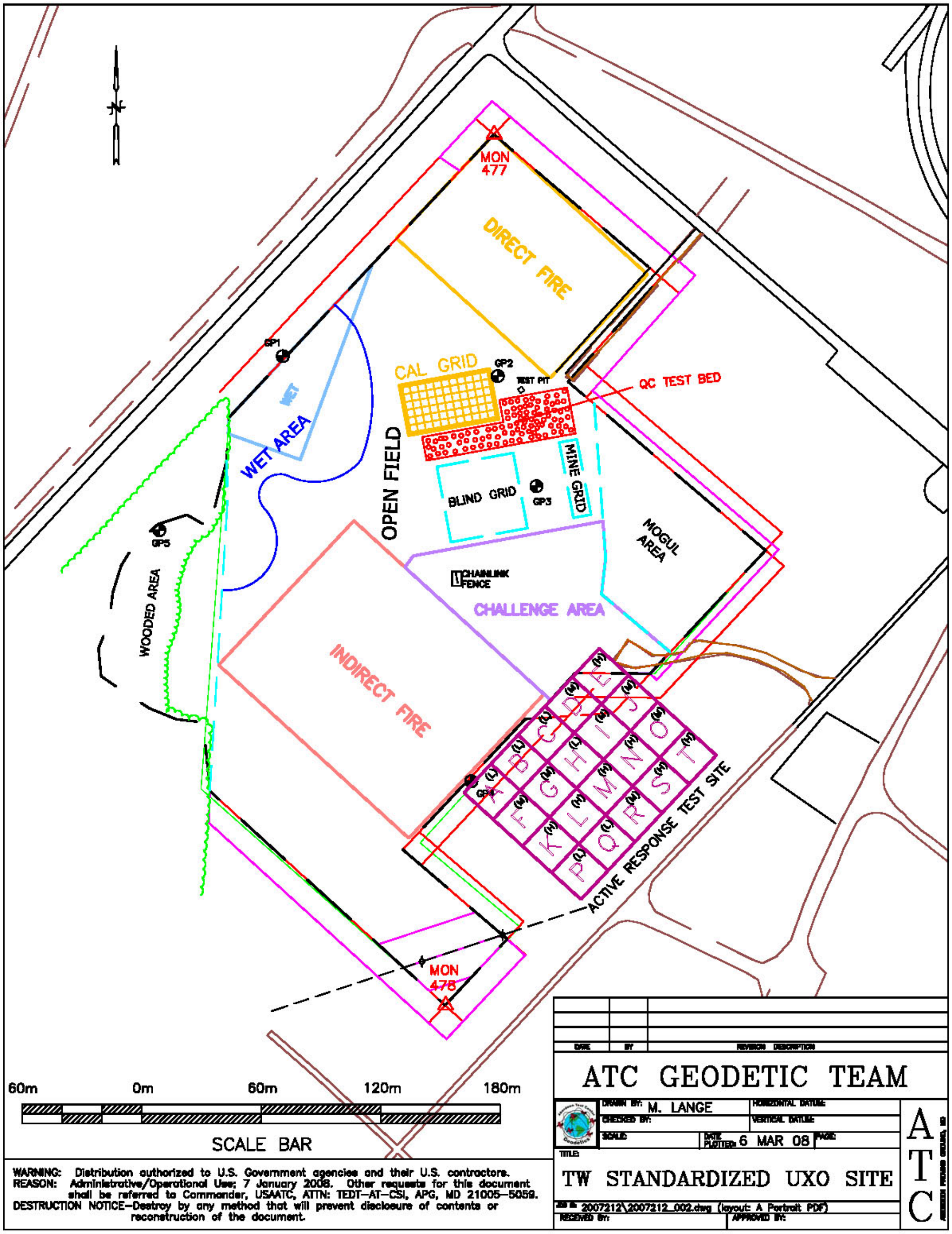


Figure 2. Test site layout.

2.2.4 Standard and Nonstandard Inert Munitions Targets

The standard and nonstandard munitions items emplaced in the test areas are provided in Table 2. Standardized targets are members of a set of specific munitions items that have identical properties to all other items in the set (caliber, configuration, size, weight, aspect ratio, material, filler, magnetic remanence, and nomenclature). Nonstandard targets are inert munitions items having properties that differ from those in the set of standardized items.

2.3 ATC SURVEY COMMENTS

None.

TABLE 2. INERT MUNITIONS TARGETS

Item	Munition Type	Calibration Lanes	Blind Grid	Open Field Direct Fire	Open Field Indirect Fire	Open Field Legacy	Moguls	Woods
20-mm Projectile M55	S	X				X	X	X
25-mm Projectile M794	S	X	X	X				
37-mm Projectile M47	S	X	X	X				
40-mm Projectile MKII Bodies	S	X				X	X	X
BDU-28 Submunition	S	X				X	X	X
BLU-26 Submunition	S	X				X	X	X
M42 Submunition	S	X				X	X	X
57-mm Projectile APC M86	S	X				X	X	X
60-mm Mortar M49A3	S	X	X		X			
2.75-in. Rocket M230	S	X				X	X	X
81-mm Mortar M374	S	X	X		X	X	X	X
105-mm HEAT Rounds M456	S					X	X	X
105-mm HEAT Round M490	S	X	X	X				
105-mm Projectile M60	S	X	X		X	X	X	X
155-mm Projectile M483A1	S	X				X	X	X
20-mm Projectile M55	NS					X	X	X
20-mm Projectile M97	NS					X	X	X
40-mm Projectile M813	NS					X	X	X
60-mm Mortar (JPG)	NS					X	X	X
60-mm Mortar M49	NS					X	X	X
2.75-in. Rocket M230	NS					X	X	X
2.75-in. Rocket XM229	NS					X	X	X
81-mm Mortar (JPG)	NS					X	X	X
81-mm Mortar M374	NS					X	X	X
105-mm Projectile M60	NS					X	X	X
155-mm Projectile M483A	NS					X	X	X

HEAT = High-explosive antitank.
JPG = Jefferson Proving Ground.
NS = Nonstandard munition.
S = Standard munition.

SECTION 3. FIELD DATA

3.1 DATE OF FIELD ACTIVITIES

Date: 26 through 30 November 2012.

3.2 AREAS TESTED/NUMBER OF HOURS

Areas tested and total numbers of hours operated at each site are provided in Table 3.

TABLE 3. AREAS TESTED AND NUMBER OF HOURS

Area	No. of Hours
Calibration lanes	0.75
Blind grid	4.16
Open field	-
Woods	-
Mogul	-
Mine grid	-

Note: Table 3 represents the total time spent in each area.

3.3 TEST CONDITIONS

3.3.1 Weather Conditions

An APG weather station located approximately 1 mi west of the test site was used to record average temperature and precipitation on a half-hour basis for each day of operation. The temperatures presented in Table 4 represent the average temperature during field operations from 0700 to 1700 hr, while precipitation data represent a daily total amount of rainfall. Hourly weather logs used to generate this summary are provided in Appendix B.

TABLE 4. TEMPERATURE/PRECIPITATION DATA SUMMARY

Date, 2012	Average Temperature, ^{o}F	Total Daily Precipitation, in.
26 November	43.4	0.00
27 November	37.8	0.33
28 November	39.9	0.00
29 November	40.6	0.00
30 November	40.7	0.00

3.3.2 Field Conditions

Battelle surveyed the calibration grid and blind grid areas. A few small puddles and wet areas from rain prior to and during testing were present.

3.3.3 Soil Moisture

Three soil probes were placed at various locations within the site to capture soil moisture data: blind grid, calibration, open field, and wooded areas. Measurements were collected in percent moisture and were taken twice daily (morning and afternoon) from five different soil depths (1 to 6 in., 6 to 12 in., 12 to 24 in., 24 to 36 in., and 36 to 48 in.) from each probe. Soil moisture logs are provided in Appendix C.

3.4 FIELD ACTIVITIES

3.4.1 Setup/Mobilization

These activities included initial mobilization and daily equipment preparation and breakdown. A five-person crew took 8 hr and 30 min to perform the initial setup and mobilization. Fifteen minutes of equipment preparation was accrued, and end of day equipment breakdown totaled 50 min.

3.4.2 Calibration

Battelle spent 45 min in the calibration lanes, of which 30 min were spent collecting data. One calibration exercise totaling 15 min occurred while surveying the Calibration Grid.

3.4.3 Downtime Occasions

Occasions of downtime are grouped into five categories: equipment/data checks or equipment maintenance, equipment failure and repair, weather, demonstration site issues, or breaks/lunch. All downtime is included for the purposes of calculating labor requirements (section 5) except for downtime due to demonstration site issues. Demonstration site issues, while noted in the daily log, are considered nonchargeable downtime for the purposes of calculating labor costs and are not discussed. Breaks and lunches are discussed in this section and billed to the total site survey area.

3.4.3.1 Equipment/data checks, maintenance. Equipment data checks and maintenance activities accounted for no site usage time. These activities included changing out batteries and performing routine data checks to ensure the data were being properly recorded/collected. Battelle spent 25 min for breaks and lunches.

3.4.3.2 Equipment failure or repair. No equipment failures occurred during the Blind Grid survey.

3.4.3.3 Weather. No weather delays occurred during the Blind Grid survey.

3.4.4 Data Collection

TABLE 5. TOTAL TIME BATTELLE, SPENT PER AREA

Area	Time, hr/min
Blind grid	2 hrs, 30 min
Open field	-
Legacy	-
Direct fire	-
Indirect fire	-
Challenge	-
Wooded	-
Mine grid	-
Moguls	-

Note: Table 5 represents the total time spent in each area collecting data.

3.4.5 Demobilization

The Battelle survey crew conducted a demonstration of the calibration, blind and small munition grids. Demobilization occurred on 30 November 2012. On that day, it took the crew 3 hr and 55 min to break down and pack up their equipment.

3.5 PROCESSING TIME

Battelle submitted the raw data from the demonstration activities on the last day of the demonstration, as required. The scoring submittal data was provided 13 August 2013.

3.6 DEMONSTRATOR'S FIELD PERSONNEL

Jeff Gamey
William Doll
Jeannemarie Norton
Marcus Patrick Watson
David Thomas Bell

3.7 DEMONSTRATOR'S FIELD SURVEYING METHOD

Battelle collected the data on a linear basis using a line spacing of 1.5 m.

3.8 SUMMARY OF DAILY LOGS

Daily logs capture all field activities during this demonstration and are provided in Appendix D.

SECTION 4. TECHNICAL PERFORMANCE RESULTS

4.1 ROC CURVES USING ALL MUNITIONS CATEGORIES

The probability of detection for the response stage (P_d^{res}) and the discrimination stage (P_d^{disc}) versus their respective probability of clutter detection or probability of false positive within each area are shown in Figures 3 through 8. The probabilities plotted against their respective BAR within each area are shown in Figures 9 through 14. Both figures use horizontal lines to illustrate the performance of the demonstrator at two demonstrator-specified points: at the system noise level for the response stage, representing the point below which targets are not considered detectable, and at the demonstrator's recommended threshold level for the discrimination stage, defining the subset of targets the demonstrator would recommend digging based on discrimination. Note that all points have been rounded to protect the GT.

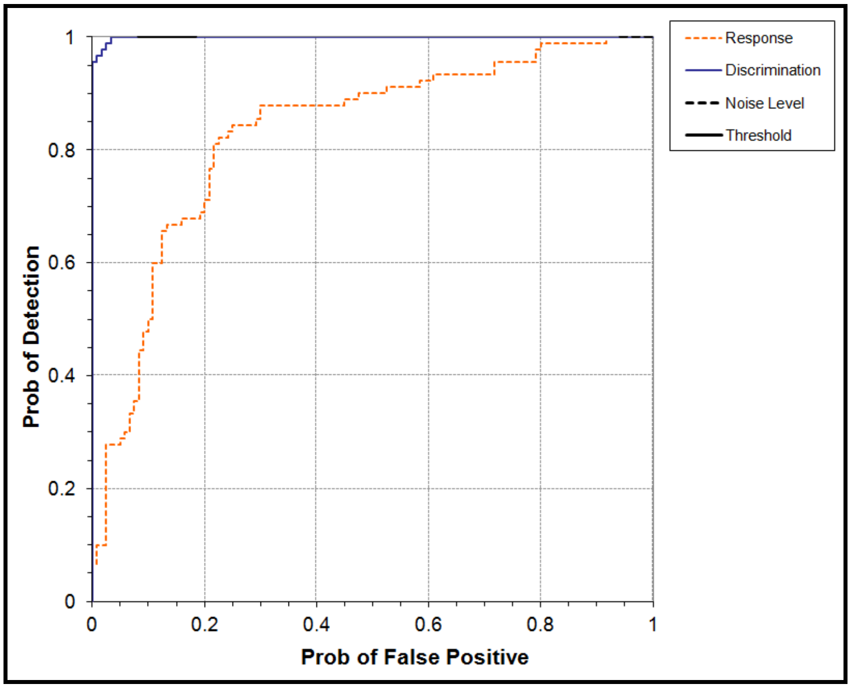


Figure 3. TEM-8G/towed blind grid probability of detection for response and discrimination stages versus their respective probability of false positive.

Not covered

Figure 4. TEM-8G/towed open field (direct fire) probability of detection for response and discrimination stages versus their respective probability of false positive.

Not covered

Figure 5. TEM-8G/towed open field (indirect fire) probability of detection for response and discrimination stages versus their respective probability of false positive.

Not covered

Figure 6. TEM-8G/towed open field (legacy) probability of detection for response and discrimination stages versus their respective probability of false positive.

Not covered

Figure 7. TEM-8G/towed wooded probability of detection for response and discrimination stages versus their respective probability of false positive.

Not covered

Figure 8. TEM-8G/towed mogul probability of detection for response and discrimination stages versus their respective probability of false positive.

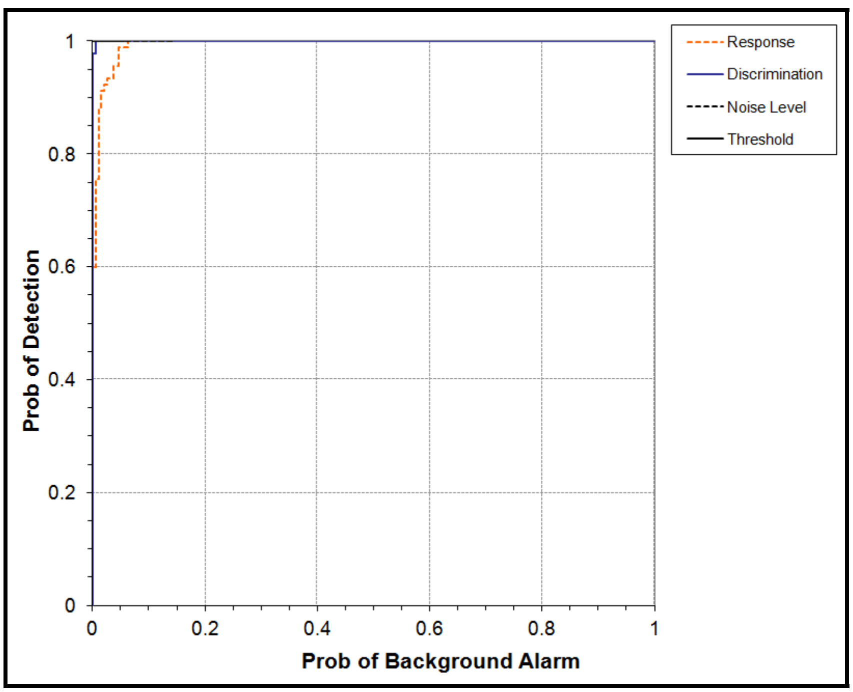


Figure 9. TEM-8G/towed blind grid probability of detection for response and discrimination stages versus their respective probability of background alarm.

Not covered

Figure 10. TEM-8G/towed open field (direct fire) probability of detection for response and discrimination stages versus their respective background alarm rate.

Not covered

Figure 11. TEM-8G/towed open field (indirect fire) probability of detection for response and discrimination stages versus their respective background alarm rate.

Not covered

Figure 12. TEM-8G/towed open field (legacy) probability of detection for response and discrimination stages versus their respective background alarm rate.

Not covered

Figure 13. TEM-8G/towed wooded probability of detection for response and discrimination stages versus their respective background alarm rate.

Not covered

Figure 14. TEM-8G/towed mogul probability of detection for response and discrimination stages versus their respective background alarm rate.

4.2 PERFORMANCE SUMMARIES

Results for each of the testing areas are presented in Tables 6 (for labor requirements, see section 5). The response stage results are derived from the list of anomalies above the demonstrator-provided noise level. The results for the discrimination stage are derived from the demonstrator's recommended threshold for optimizing munitions-related cleanup by minimizing false alarm digs and maximizing munitions recovery. The lower and upper 90-percent confidence limits on P_d, P_{cd}, and P_{fp} were calculated assuming that the number of detections and false positives are binomially distributed random variables.

TABLE 6a. BLIND GRID TEST AREA RESULTS

	Response Stage				Discrimination Stage			
Munitions[a] Scores	Pd^{res}: by type				Pd^{disc}: by type			
	All Types	**105-mm**	**81/60-mm**	**37/25-mm**	**All Types**	**105-mm**	**81/60-mm**	**37/25-mm**
	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	0.98	0.93	0.93	0.93	0.98	0.93	0.93	0.93
By Depth[b]								
0 to 4D	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
4D to 8D	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
8D to 12D	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Clutter Scores	P_{cd}				P_{fp}			
By Mass								
By Depth[b]	**All Mass**	**0 to 0.25 kg**	**>0.25 to 1 kg**	**>1 to 8 kg**	**All Mass**	**0 to 0.25 kg**	**>0.25 to 1 kg**	**>1 to 8 kg**
All Depth	1.00				0.18			
	0.99	0.98	1.00	1.00	0.13	0.07	0.12	0.60
	0.97				0.09			
0 to 0.15 m	0.99	0.98	1.00	1.00	0.11	0.08	0.07	0.67
0.15 to 0.3 m	1.00	1.00	1.00	1.00	0.31	0.00	0.43	0.50
0.3 to 0.6 m	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Background Alarm Rates								
	P_{ba}^{res}: 0.10				P_{ba}^{disc}: 0.01			

[a]In cells with offset data entries, the numbers to the left are the result and the two numbers to the right are an upper and lower 90-percent confidence interval for an assumed binomial distribution.
[b]All depths are measured to the center of the object.

TABLE 6b. OPEN FIELD DIRECT FIRE TEST AREA RESULTS (not covered)

	Response Stage				Discrimination Stage			
Munitions[a] Scores	P_d^{res}: *by type*				P_d^{disc}: *by type*			
	All Types	**105-mm**	**81-mm**	**60-mm**	**All Types**	**105-mm**	**81-mm**	**60-mm**
	-- -- --	-- -- --	-- -- --	-- -- --	-- -- --	-- -- --	-- -- --	-- -- --
By Density								
High	--	--	--	--	--	--	--	--
Medium	--	--	--	--	--	--	--	--
Low	--	--	--	--	--	--	--	--
By Depth[b]								
0 to 4D	--	--	--	--	--	--	--	--
4D to 8D	--	--	--	--	--	--	--	--
8D to 12D	--	--	--	--	--	--	--	--
Clutter Scores	P_{cd}				P_{fp}			
By Mass								
By Depth[b]	**All Mass**	**0 to 0.25 kg**	**>0.25 to 1 kg**	**>1 to 8 kg**	**All Mass**	**0 to 0.25 kg**	**>0.25 to 1 kg**	**>1 to 8 kg**
All Depth	-- -- --	--	--	--	-- -- --	--	--	--
0 to 0.15 m	--	--	--	--	--	--	--	--
0.15 to 0.3 m	--	--	--	--	--	--	--	--
0.3 to 0.6 m	--	--	--	--	--	--	--	--
Background Alarm Rates								
	BAR^{res}: --				**BAR^{disc}:** --			
Groups								
Found	--				--			
Identified	--				--			
Coverage	--				--			

[a]In cells with offset data entries, the numbers to the left are the result and the two numbers to the right are an upper and lower 90-percent confidence interval for an assumed binomial distribution.
[b]All depths are measured to the center of the object.

TABLE 6c. OPEN FIELD INDIRECT FIRE TEST AREA RESULTS (not covered)

Response Stage					Discrimination Stage			
Munitions[a] Scores	***P_d^{res}: by type***				***P_d^{disc}: by type***			
	All Types	**105-mm**	**81-mm**	**60-mm**	**All Types**	**105-mm**	**81-mm**	**60-mm**
	-- -- --	-- -- --	-- -- --	-- -- --	-- -- --	-- -- --	-- -- --	-- -- --
By Density								
High	--	--	--	--	--	--	--	--
Medium	--	--	--	--	--	--	--	--
Low	--	--	--	--	--	--	--	--
By Depth[b]								
0 to 4D	--	--	--	--	--	--	--	--
4D to 8D	--	--	--	--	--	--	--	--
8D to 12D	--	--	--	--	--	--	--	--
Clutter Scores	***P_{cd}***				***P_{fp}***			
By Mass								
By Depth[b]	**All Mass**	**0 to 0.25 kg**	**>0.25 to 1 kg**	**>1 to 8 kg**	**All Mass**	**0 to 0.25 kg**	**>0.25 to 1 kg**	**>1 to 8 kg**
All Depth	-- -- --	--	--	--	-- -- --	--	--	--
0 to 0.15 m	--	--	--	--	--	--	--	--
0.15 to 0.3 m	--	--	--	--	--	--	--	--
0.3 to 0.6 m	--	--	--	--	--	--	--	--
Background Alarm Rates								
BAR^{res}: --					**BAR^{disc}: --**			
Groups								
Found	--				--			
Identified	--				--			
Coverage	--				--			

[a]In cells with offset data entries, the numbers to the left are the result and the two numbers to the right are an upper and lower 90-percent confidence interval for an assumed binomial distribution.
[b]All depths are measured to the center of the object.

TABLE 6d. OPEN FIELD LEGACY TEST AREA RESULTS (not covered)

	Response Stage				Discrimination Stage			
	P_d^{res}: by type				*P_d^{disc}: by type*			
Munitions[a] Scores	**All Types**	**Small**	**Medium**	**Large**	**All Types**	**Small**	**Medium**	**Large**
	-- -- --	-- -- --	-- -- --	-- -- --	-- -- --	-- -- --	-- -- --	-- -- --
	By Depth[b]							
0 to 4D	--	--	--	--	--	--	--	--
4D to 8D	--	--	--	--	--	--	--	--
8D to 12D	--	--	--	--	--	--	--	--
> 12D	--	--	--	--	--	--	--	--

Clutter Scores	P_{cd}					P_{fp}				
	By Mass									
By Depth[b]	**All Mass**	**0 to 0.25 kg**	**>0.25 to 1 kg**	**>1 to 10 kg**	**> 10 kg**	**All Mass**	**0 to 0.25 kg**	**>0.25 to 1 kg**	**>1 to 8 kg**	**< 10kg**
All Depth	-- -- --	--	--	--	--	-- -- --	--	--	--	--
0 to 0.15 m	--	--	--	--	--	--	--	--	--	--
0.15 to 0.3 m	--	--	--	--	--	--	--	--	--	--
0.3 to 0.6 m	--	--	--	--	--	--	--	--	--	--
> 0.6 m	--	--	--	--	--	--	--	--	--	--

Background Alarm Rates								
	BAR^{res}:				**BAR^{disc}:**			
	Groups							
Found	--				--			
Identified	--				--			
Coverage	--				--			

[a]In cells with offset data entries, the numbers to the left are the result and the two numbers to the right are an upper and lower 90-percent confidence interval for an assumed binomial distribution.
[b]All depths are measured to the center of the object.

TABLE 6e. WOODED TEST AREA RESULTS (not covered)

	Response Stage				Discrimination Stage			
	P_d^{res}: by type				***P_d^{disc}: by type***			
Munitions[a] Scores	**All Types**	**Small**	**Medium**	**Large**	**All Types**	**Small**	**Medium**	**Large**
	-- -- --	-- -- --	-- -- --	-- -- --	-- -- --	-- -- --	-- -- --	-- -- --
				By Depth[b]				
0 to 4D	--	--	--	--	--	--	--	--
4D to 8D	--	--	--	--	--	--	--	--
8D to 12D	--	--	--	--	--	--	--	--
> 12D	--	--	--	--	--	--	--	--

Clutter Scores	***P_{cd}***					***P_{fp}***				
					By Mass					
By Depth[b]	**All Mass**	**0 to 0.25 kg**	**>0.25 to 1 kg**	**>1 to 10 kg**	**> 10 kg**	**All Mass**	**0 to 0.25 kg**	**>0.25 to 1 kg**	**>1 to 8 kg**	**< 10kg**
All Depth	-- -- --	--	--	--	--	-- -- --	--	--	--	--
0 to 0.15 m	--	--	--	--	--	--	--	--	--	--
0.15 to 0.3 m	--	--	--	--	--	--	--	--	--	--
0.3 to 0.6 m	--	--	--	--	--	--	--	--	--	--
> 0.6 m	--	--	--	--	--	--	--	--	--	--

				Background Alarm Rates				
	BAR^{res}:				**BAR^{disc}:**			
				Groups				
Found	--				--			
Identified	--				--			
Coverage	--				--			

[a]In cells with offset data entries, the numbers to the left are the result and the two numbers to the right are an upper and lower 90-percent confidence interval for an assumed binomial distribution.

[b]All depths are measured to the center of the object.

TABLE 6f. MOGUL TEST AREA RESULTS (not covered)

	Response Stage				Discrimination Stage			
	P_d^{res}: *by type*				P_d^{disc}: *by type*			
Munitions[a] Scores	**All Types**	**Small**	**Medium**	**Large**	**All Types**	**Small**	**Medium**	**Large**
	-- -- --	-- -- --	-- -- --	-- -- --	-- -- --	-- -- --	-- -- --	-- -- --
	By Depth[b]							
0 to 4D	--	--	--	--	--	--	--	--
4D to 8D	--	--	--	--	--	--	--	--
8D to 12D	--	--	--	--	--	--	--	--
> 12D	--	--	--	--	--	--	--	--

Clutter Scores	P_{cd}					P_{fp}				
	By Mass									
By Depth[b]	**All Mass**	**0 to 0.25 kg**	**>0.25 to 1 kg**	**>1 to 10 kg**	**> 10 kg**	**All Mass**	**0 to 0.25 kg**	**>0.25 to 1 kg**	**>1 to 8 kg**	**< 10kg**
All Depth	-- -- --	--	--	--	--	-- -- --	--	--	--	--
0 to 0.15 m	--	--	--	--	--	--	--	--	--	--
0.15 to 0.3 m	--	--	--	--	--	--	--	--	--	--
0.3 to 0.6 m	--	--	--	--	--	--	--	--	--	--
> 0.6 m	--	--	--	--	--	--	--	--	--	--
	Background Alarm Rates									
	BAR^{res}:					**BAR^{disc}:**				
	Groups									
Found	--					--				
Identified	--					--				
Coverage	--					--				

[a]In cells with offset data entries, the numbers to the left are the result and the two numbers to the right are an upper and lower 90-percent confidence interval for an assumed binomial distribution.
[b]All depths are measured to the center of the object.

4.3 EFFICIENCY, REJECTION RATES, AND TYPE CLASSIFICATION

Efficiency and rejection rates are calculated to quantify the discrimination ability at specific points of interest on the ROC curve: (1) at the point where no decrease in P_d is suffered (i.e., the efficiency is by definition equal to one) and (2) at the operator selected threshold. These values are presented in Tables 7a through 7d.

TABLE 7a. BLIND GRID EFFICIENCY AND REJECTION RATES

	Efficiency (E)	False Positive Rejection Rate	Background Alarm Rejection Rate
At Operating Point	1.00	0.87	0.95
With No Loss of P_d	1.00	0.97	0.94

TABLE 7b. OPEN FIELD (DIRECT) EFFICIENCY AND REJECTION RATES (not covered)

	Efficiency (E)	False Positive Rejection Rate	Background Alarm Rejection Rate
At Operating Point	--	--	--
With No Loss of P_d	--	--	--

TABLE 7c. OPEN FIELD (INDIRECT) EFFICIENCY AND REJECTION RATES (not covered)

	Efficiency (E)	False Positive Rejection Rate	Background Alarm Rejection Rate
At Operating Point	--	--	--
With No Loss of P_d	--	--	--

TABLE 7d. OPEN FIELD (LEGACY) EFFICIENCY AND REJECTION RATES (not covered)

	Efficiency (E)	False Positive Rejection Rate	Background Alarm Rejection Rate
At Operating Point	--	--	--
With No Loss of P_d	--	--	--

TABLE 7e. WOODED EFFICIENCY AND REJECTION RATES (not covered)

	Efficiency (E)	False Positive Rejection Rate	Background Alarm Rejection Rate
At Operating Point	--	--	--
With No Loss of P_d	--	--	--

TABLE 7f. MOGUL EFFICIENCY AND REJECTION RATES (not covered)

	Efficiency (E)	False Positive Rejection Rate	Background Alarm Rejection Rate
At Operating Point	--	--	--
With No Loss of P_d	--	--	--

At the demonstrator's recommended setting, the munitions items that were detected and correctly discriminated were further scored on whether their correct type could be identified (tables 8a through 8f). Correct type examples include 20-mm projectile, 105-mm HEAT projectile, and 2.75-in. rocket. A list of the standard type declaration required for each munitions item was provided to demonstrators prior to testing. The standard types for the three example items are 20-mmP, 105H, and 2.75-in.

TABLE 8a. BLIND GRID CORRECT TYPE CLASSIFICATION OF TARGETS CORRECTLY DISCRIMINATED AS MUNITIONS

Size	Percentage Correct
25mm	100%
37mm	100%
60mm	100%
81mm	93%
105mm	93%
105 artillery	93%
Overall	97%

Note: The demonstrator did not attempt to provide type classification (if applicable).

TABLE 8b. OPEN FIELD DIRECT FIRE CORRECT TYPE CLASSIFICATION OF TARGETS CORRECTLY DISCRIMINATED AS MUNITIONS (not covered)

Size	Percentage Correct
25mm	--
37mm	--
105mm	--
Overall	--

TABLE 8c. OPEN FIELD INDIRECT FIRE CORRECT TYPE CLASSIFICATION OF TARGETS CORRECTLY DISCRIMINATED AS MUNITIONS (not covered)

Size	Percentage Correct
60mm	--
81mm	--
105mm	--
Overall	--

TABLE 8d. OPEN FIELD LEGACY CORRECT TYPE CLASSIFICATION OF TARGETS CORRECTLY DISCRIMINATED AS MUNITIONS (not covered)

Size	Percentage Correct
Small	--
Medium	--
Large	--
Overall	--

TABLE 8e. WOODED CORRECT TYPE CLASSIFICATION OF TARGETS CORRECTLY DISCRIMINATED AS MUNITIONS (not covered)

Size	Percentage Correct
Small	--
Medium	--
Large	--
Overall	--

TABLE 8f. MOGUL CORRECT TYPE CLASSIFICATION OF TARGETS CORRECTLY DISCRIMINATED AS MUNITIONS (not covered)

Size	Percentage Correct
Small	--
Medium	--
Large	--
Overall	--

4.4 LOCATION ACCURACY

The mean location error and standard deviations appear in Tables 9a through 9f. These calculations are based on average missed distance for munitions correctly identified during the response stage. Depths are measured from the center of the munitions to the surface. For the blind grid, only depth errors are calculated because (X, Y) positions are known to be the centers of the grid square.

TABLE 9a. BLIND GRID MEAN LOCATION ERROR AND STANDARD DEVIATION

	Mean	Standard Deviation
Northing	N/A	N/A
Easting	N/A	N/A
Depth	0.022	0.123

TABLE 9b. OPEN FIELD DIRECT FIRE MEAN LOCATION ERROR AND STANDARD DEVIATION (not covered)

	Mean	Standard Deviation
Northing	--	--
Easting	--	--
Depth	--	--

TABLE 9c. OPEN FIELD INDIRECT FIRE MEAN LOCATION ERROR AND STANDARD DEVIATION (not covered)

	Mean	Standard Deviation
Northing	--	--
Easting	--	--
Depth	--	--

TABLE 9d. OPEN FIELD LEGACY MEAN LOCATION ERROR AND STANDARD DEVIATION (not covered)

	Mean	Standard Deviation
Northing	--	--
Easting	--	--
Depth	--	--

TABLE 9e. WOODED MEAN LOCATION ERROR AND STANDARD DEVIATION (not covered)

	Mean	Standard Deviation
Northing	--	--
Easting	--	--
Depth	--	--

TABLE 9f. MOGUL MEAN LOCATION ERROR AND STANDARD DEVIATION (not covered)

	Mean	Standard Deviation
Northing	--	--
Easting	--	--
Depth	--	--

SECTION 5. APPENDIXES

APPENDIX A. TERMS AND DEFINITIONS

GENERAL DEFINITIONS

Anomaly: Location of a system response deemed to warrant further investigation by the demonstrator for consideration as an emplaced munitions item.

Detection: An anomaly location that is within R_{halo} of an emplaced munitions item.

Military Munitions (MM): Specific categories of MM that may pose unique explosive safety risks, including UXO as defined in 10 USC 101(e)(5), DMM as defined in 10 USC 2710(e)(2) and/or munitions constituents (e.g., TNT, RDX) as defined in 10 USC 2710(e)(3) that are present in high enough concentrations to pose an explosive hazard.

Emplaced Munitions: A munitions item buried by the government at a specified location in the test site.

Emplaced Clutter: A clutter item (i.e., nonmunitions item) buried by the government at a specified location in the test site.

R_{halo}: A predetermined radius about an emplaced item (clutter or munitions) within which an anomaly identified by the demonstrator as being of interest is considered to be a detection of that item. For the purpose of this program, a circular halo 0.5 meters in radius is placed around the center of the object for all clutter and munitions items.

Small Munitions: Caliber of munitions less than or equal to 40 mm (includes 20-mm projectile, 25-mm projectile, 37-mm projectile, 40-mm projectile, submunitions BLU-26, BLU-63, and M42).

Medium Munitions: Caliber of munitions greater than 40 mm and less than or equal to 81 mm (includes 57-mm projectile, 60-mm mortar, 2.75-inch rocket, and 81-mm mortar).

Large Munitions: Caliber of munitions greater than 81 mm (includes 105-mm HEAT, 105-mm projectile, and 155-mm projectile).

Group: Two or more adjacent GT items with overlapping halos.

GT: Ground truth

Response Stage Noise Level: The level that represents the signal level below which anomalies are not considered detectable. Demonstrators are required to provide the recommended noise level for the blind grid test area.

Discrimination Stage Threshold: The demonstrator-selected threshold level that is expected to provide optimum performance of the system by retaining all detectable munitions and rejecting the maximum amount of clutter. This level defines the subset of anomalies the demonstrator would recommend digging based on discrimination.

Binomially Distributed Random Variable: A random variable of the type which has only two possible outcomes, say success and failure, is repeated for *n* independent trials with the probability *p* of success and the probability *1-p* of failure being the same for each trial. The number of successes *x* observed in the *n* trials is an estimate of *p* and is considered to be a binomially distributed random variable.

RESPONSE AND DISCRIMINATION STAGE DATA

The scoring of the demonstrator's performance is conducted in two stages: response stage and discrimination stage. For both stages, the probability of detection (P_d) and the false alarms are reported as receiver-operating characteristic (ROC) curves. False alarms are divided into those anomalies that correspond to emplaced clutter items, measuring the probability of clutter detection (P_{cd}) or probability of false positive (P_{fp}). Those that do not correspond to any known item are termed background alarms.

The response stage is a measure of whether the sensor can detect an object of interest. For a channel instrument, this value should be closely related to the amplitude of the signal. The demonstrator must report the response level (threshold) below which target responses are deemed insufficient to warrant further investigation. At this stage, minimal processing may be done. This includes filtering long- and short-scale variations, bias removal, and scaling. This processing should be detailed in the data submission.

For a multichannel instrument, the demonstrator must construct a quantity analogous to amplitude. The demonstrator should consider what combination of channels provides the best test for detecting any object that the sensor can detect. The average amplitude across a set of channels is an example of an acceptable response stage quantity. Other methods may be more appropriate for a given sensor. Again, minimal processing can be done, and the demonstrator should explain how this quantity was constructed in their data submission.

The discrimination stage evaluates the demonstrator's ability to correctly identify munitions as such, and to reject clutter. For the same locations as in the response stage anomaly list, the discrimination stage list contains the output of the algorithms applied in the discrimination-stage processing. This list is prioritized based on the demonstrator's determination that an anomaly location is likely to contain munitions. Thus, higher output values are indicative of higher confidence that a munitions item is present at the specified location. For electronic signal processing, priority ranking is based on algorithm output. For other systems, priority ranking is based on human judgment. The demonstrator also selects the threshold that the demonstrator believes will provide optimum system performance, (i.e., that retains all the detected munitions and rejects the maximum amount of clutter).

Note: The two lists provided by the demonstrator contain identical numbers of potential target locations. They differ only in the priority ranking of the declarations.

GROUP SCORING FACTORS

Based on configuration of the GT at the standardized sites and the defined scoring methodology, there exists munitions groups defined as having overlapping halos. In these cases, the following scoring logic is implemented (fig. A-1 through A-9):

a. Overall site scores (i.e., P_d) will consider only isolated munitions and clutter items.

b. GT items that have overlapping halos (both munitions and clutter) will form a group and groups may form chains.

c. Groups will have a complex halos composed of all the composite halos of all its GT items.

d. Groups will have three scoring factors: groups found groups identified and group coverage. Scores will be based on 1:1 matches of anomalies and GT.

(1) Groups Found (Found): the number of groups that have one or more GT items matched divided by the total number of groups. Demonstrators will be credited with detecting a group if any item within the group is matched to an anomaly in their list.

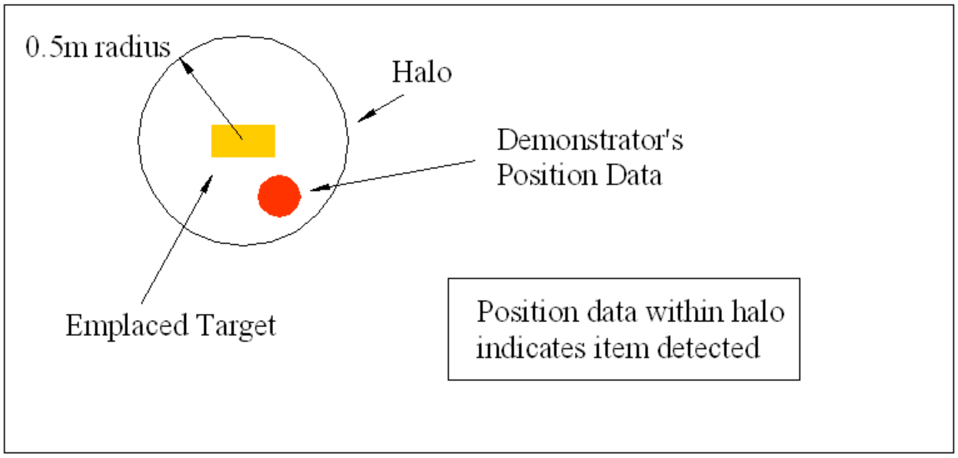
(2) Groups Identified (ID): the number of groups that have two or more GT items matched divided by the total number of groups. Demonstrators will be credited with identifying that a group is present if multiple items within the composite halo are matched to anomalies in their list.

(3) Group Coverage (Coverage): the number of GT items matched within groups divided by the total number of GT items within groups. This metric measures the demonstrator accuracy in determining the number of anomalies within a group. If five items are present and only two anomalies are matched, the demonstrator will score 0.4. If all five are matched the demonstrator will score 1.0.

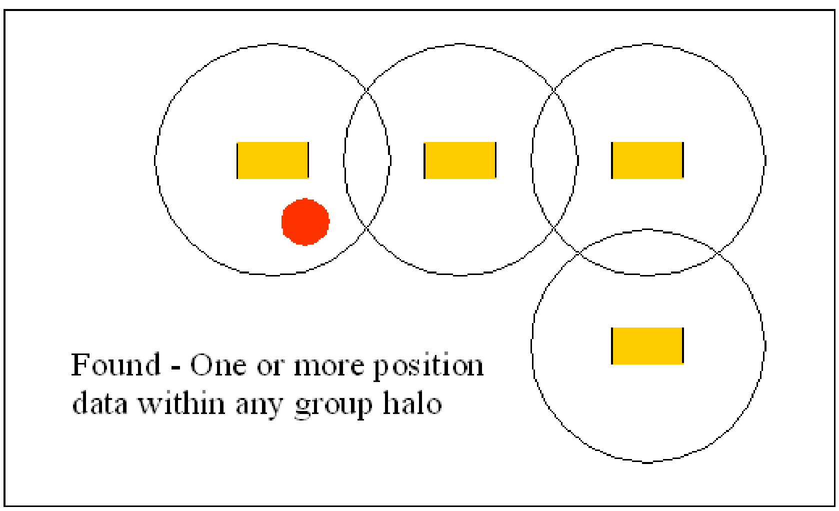
e. Location error will not be reported for groups.

f. Demonstrators will not be asked to call out groups in their scoring submissions. If multiple anomalies are indicated in a small area, the demonstrator will report all individual anomalies.

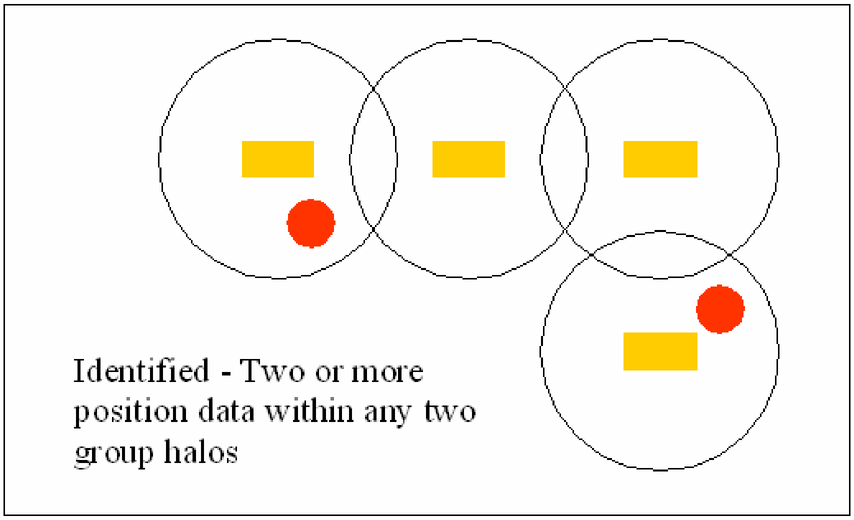
g. Excess alarms within a halo will be disregarded.



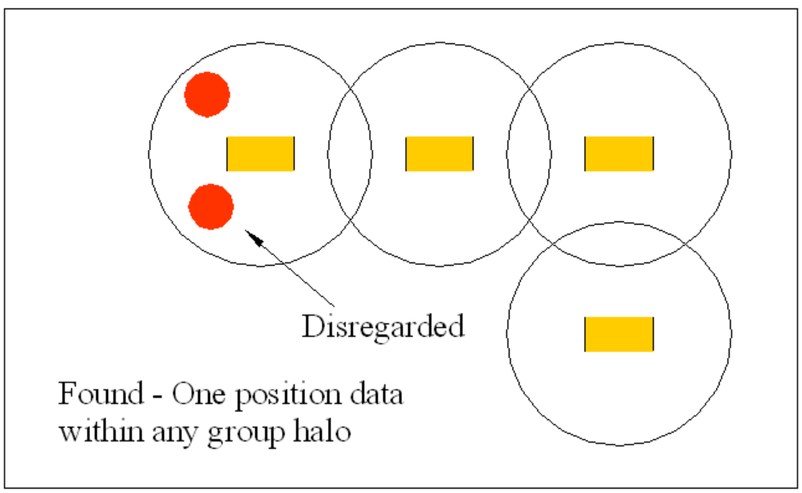
A-1. Example of detected item.



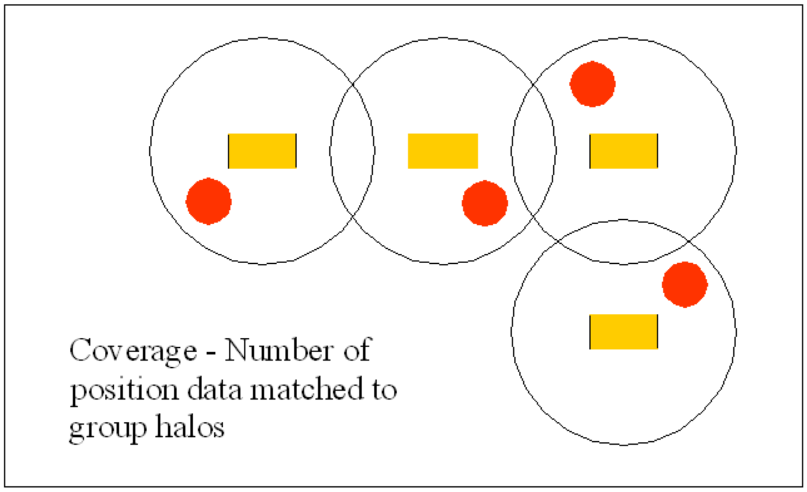
A-2. Example of group found (found).



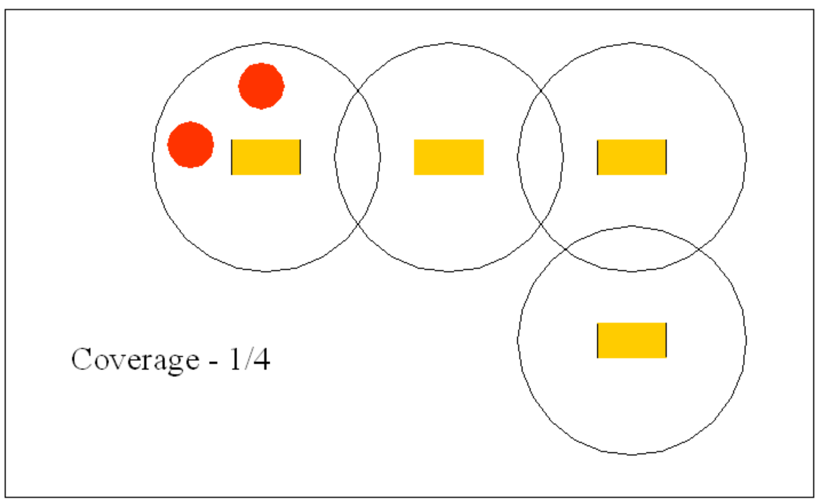
A-3. Example of group identified (ID).



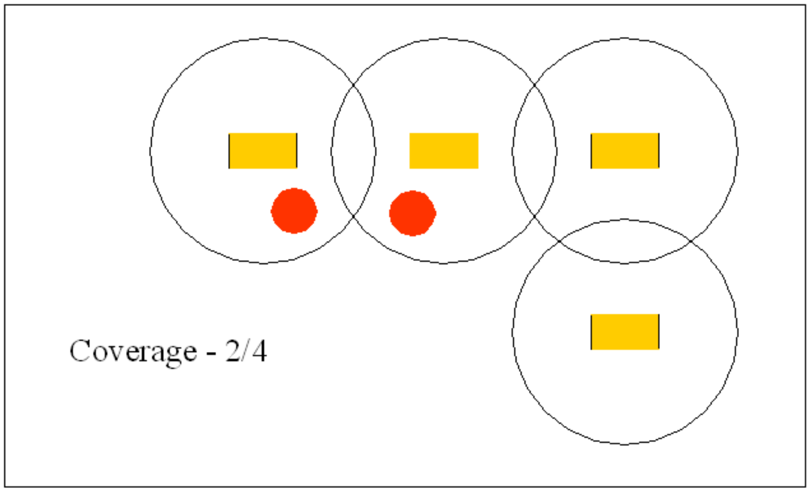
A-4. Example of excess alarms disregarded.



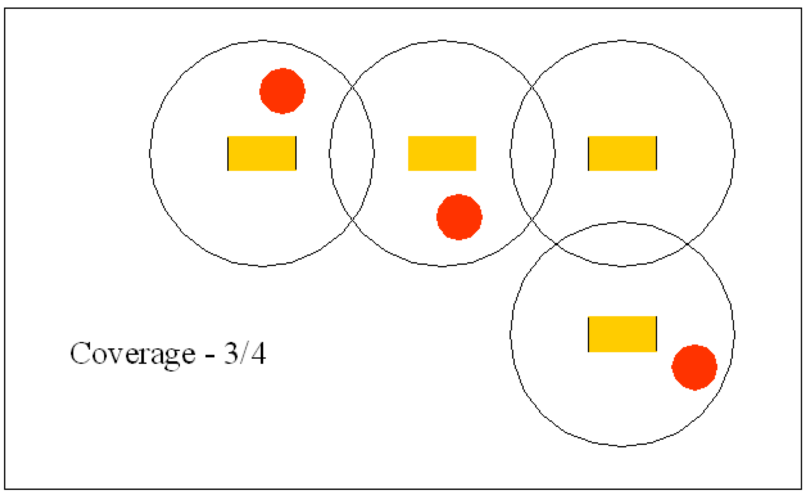
A-5. Example of a group.



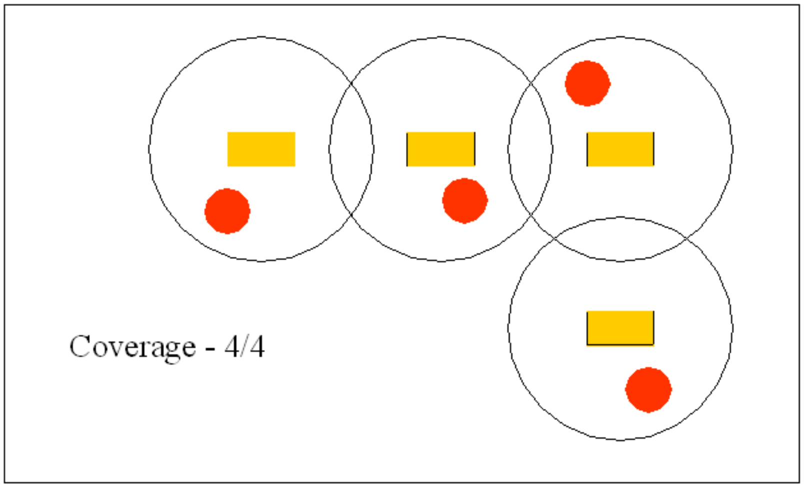
A-6. Example of group (1/4 = 0.25).



A-7. Example of group (2/4 = 0.5).



A-8. Example of group (3/4 = 0.75).



A-9. Example of group (4/4 = 1.0).

RESPONSE STAGE DEFINITIONS

Response Stage Probability of Detection (P_d^{res}): P_d^{res} = (No. of response-stage detections)/(No. of emplaced munitions in the test site).

Response Stage Clutter Detection (cd^{res}): An anomaly location that is within R_{halo} of an emplaced clutter item.

Response Stage Probability of Clutter Detection (P_{cd}^{res}): P_{cd}^{res} = (No. of response-stage clutter detections)/(No. of emplaced clutter items).

Response Stage Background Alarm (ba^{res}): An anomaly in a blind grid cell that contains neither emplaced munitions nor an emplaced clutter item. An anomaly location in the open field or scenarios that is outside R_{halo} of any emplaced munitions or emplaced clutter item.

Response Stage Probability of Background Alarm (P_{ba}^{res}): Blind grid only: P_{ba}^{res} = (No. of response-stage background alarms)/(No. of empty grid locations).

Response Stage Background Alarm Rate (BAR^{res}): Open field any challenge area (including the direct and indirect firing sub areas) only: BAR^{res} = (No. of response-stage background alarms)/(arbitrary constant).

Note that the quantities P_d^{res}, P_{cd}^{res}, P_{ba}^{res}, and BAR^{res} are functions of t^{res}, the threshold applied to the response-stage signal strength. These quantities can therefore be written as $P_d^{res}(t^{res})$, $P_{cd}^{res}(t^{res})$, $P_{ba}^{res}(t^{res})$, and $BAR^{res}(t^{res})$.

DISCRIMINATION STAGE DEFINITIONS

Discrimination: The application of a signal processing algorithm or human judgment to sensor data to discriminate munitions from clutter. Discrimination should identify anomalies that the demonstrator has high confidence correspond to munitions, as well as those that the demonstrator has high confidence correspond to nonmunitions or background returns. The former should be ranked with highest priority and the latter with lowest.

Discrimination Stage Probability of Detection (P_d^{disc}): P_d^{disc} = (No. of discrimination-stage detections)/(No. of emplaced munitions in the test site).

Discrimination Stage False Positive (fp^{disc}): An anomaly location that is within R_{halo} of an emplaced clutter item.

Discrimination Stage Probability of False Positive (P_{fp}^{disc}): P_{fp}^{disc} = (No. of discrimination stage false positives)/(No. of emplaced clutter items).

Discrimination Stage Background Alarm (ba^{disc}): An anomaly in a blind grid cell that contains neither emplaced munitions nor an emplaced clutter item. An anomaly location in the open field or scenarios that is outside R_{halo} of any emplaced munitions or emplaced clutter item.

Discrimination Stage Probability of Background Alarm (P_{ba}^{disc}): P_{ba}^{disc} = (No. of discrimination-stage background alarms)/(No. of empty grid locations).

Discrimination Stage Background Alarm Rate (BAR^{disc}): BAR^{disc} = (No. of discrimination-stage background alarms)/(arbitrary constant).

Note that the quantities P_d^{disc}, P_{fp}^{disc}, P_{ba}^{disc}, and BAR^{disc} are functions of t^{disc}, the threshold applied to the discrimination-stage signal strength. These quantities can therefore be written as $P_d^{disc}(t^{disc})$, $P_{fp}^{disc}(t^{disc})$, $P_{ba}^{disc}(t^{disc})$, and $BAR^{disc}(t^{disc})$.

RECEIVER-OPERATING CHARACTERISTIC (ROC) CURVES

ROC curves at both the response and discrimination stages can be constructed based on the above definitions. The ROC curves plot the relationship between P_d versus P_{cd} or P_{fp} and P_d versus BAR or P_{ba} as the threshold applied to the signal strength is varied from its minimum (t_{min}) to its maximum (t_{max}) value.[1] P_d versus P_{fp} and P_d versus BAR being combined into ROC curves are shown in Figure A-10. Note that the "res" and "disc" superscripts have been suppressed from all the variables for clarity.

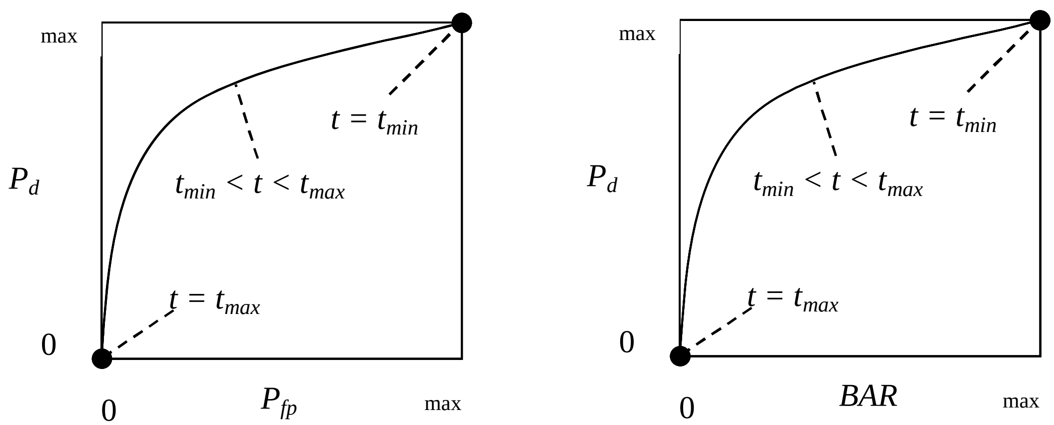


Figure A-10. ROC curves for open field testing. Each curve applies to both the response and discrimination stages.

METRICS TO CHARACTERIZE THE DISCRIMINATION STAGE

The demonstrator is also scored on efficiency and rejection ratio, which measure the effectiveness of the discrimination stage processing. The goal of discrimination is to retain the greatest number of munitions detections from the anomaly list while rejecting the maximum number of anomalies arising from nonmunitions items. The efficiency measures the fraction of detected munitions retained by the discrimination, while the rejection ratio measures the fraction of false alarms rejected. Both measures are defined relative to the entire response list, i.e., the maximum munitions detectable by the sensor and its accompanying clutter detection rate/false positive rate or background alarm rate.

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[1]Strictly speaking, ROC curves plot the P_d versus P_{ba} over a predetermined and fixed number of detection opportunities (some of the opportunities are located over munitions and others are located over clutter or blank spots). In an open field scenario, each system suppresses its signal strength reports until some bare-minimum signal response is received by the system. Consequently, the open field ROC curves do not have information from low signal-output locations, and, furthermore, different contractors report their signals over a different set of locations on the ground. These ROC curves are thus not true to the strict definition of ROC curves as defined in textbooks on detection theory. Note, however, that the ROC curves obtained in the blind grid test sites are true ROC curves.

Efficiency (E): $E = P_d^{disc}(t^{disc})/P_d^{res}(t_{min}^{res})$: Measures (at a threshold of interest) the degree to which the maximum theoretical detection performance of the sensor system (as determined by the response stage tmin) is preserved after application of discrimination techniques. Efficiency is a number between 0 and 1. An efficiency of 1 implies that all of the munitions initially detected in the response stage were retained at the specified threshold in the discrimination stage, t^{disc}.

False Positive Rejection Rate (R_{fp}): $R_{fp} = 1 - [P_{fp}^{disc}(t^{disc})/P_{cd}^{res}(t_{min}^{res})]$: Measures (at a threshold of interest) the degree to which the sensor system's false positive performance is improved over the maximum false positive performance (as determined by the response stage tmin). The rejection rate is a number between 0 and 1. A rejection rate of 1 implies that all emplaced clutter initially detected in the response stage were correctly rejected at the specified threshold in the discrimination stage.

Background Alarm Rejection Rate (R_{ba}):

Blind grid: $R_{ba} = 1 - [P_{ba}^{disc}(t^{disc})/P_{ba}^{res}(t_{min}^{res})]$.
Open field: $R_{ba} = 1 - [BAR^{disc}(t^{disc})/BAR^{res}(t_{min}^{res})])$.

Measures the degree to which the discrimination stage correctly rejects background alarms initially detected in the response stage. The rejection rate is a number between 0 and 1. A rejection rate of 1 implies that all background alarms initially detected in the response stage were rejected at the specified threshold in the discrimination stage.

CHI-SQUARE COMPARISON

The Chi-square test for differences in probabilities (or 2 by 2 contingency table) is used to analyze two samples drawn from two different populations to see if both populations have the same or different proportions of elements in a certain category. More specifically, two random samples are drawn, one from each population, to test the null hypothesis that the probability of event A (some specified event) is the same for both populations.

The test statistic of the 2 by 2 contingency table is the Chi-square distribution with one degree of freedom. When an association between a more challenging terrain feature and relatively degraded performance is sought, a one-sided test is performed. A two-sided 2 by 2 contingency table is used in the Standardized UXO Technology Demonstration Site Program to compare performance between any two areas or subareas when the direction of degradation cannot be predetermined.

For a one-sided test, a significance level of 0.05 is used to set the critical decision limit. It is a critical decision limit because if the test statistic calculated from the data exceeds this value, then the lower proportion tested will be considered significantly less than the greater one (degraded). If the test statistic calculated from the data is less than this value, then no degradation can be said to exist because of the terrain feature introduced.

For a two-sided test, a significance level of 0.10 is used to allow 0.05 on either side of the decision. It is a critical decision limit because if the test statistic calculated from the data exceeds this value, then the two proportions tested will be considered significantly different. If the test statistic calculated from the data is less than this value, then the two proportions tested will be considered not significantly different.

An exception must be applied when either a 0 or 100 percent success rate occurs in the sample data. The Chi-square test cannot be used in these instances. Instead, Fischer's test is used, and the critical decision limit for one-sided tests is the chosen significance level, which in this case is 0.05. With Fischer's test, if the test statistic is less than the critical value, then the proportions are considered to be significantly different.

An example follows that illustrates Standardized UXO Technology Demonstration Site blind grid results compared to those from the open field legacy. It should be noted that a significant result does not prove a cause-and-effect relationship exists between the two populations of interest; however, it does serve as a tool to indicate that one data set has experienced a degradation or change in system performance at a large enough level than can be accounted for merely by chance or random variation. Note also that a result that is not significant indicates that there is not enough evidence to declare that anything more than chance or random variation within the same population is at work between the two data sets being compared.

Demonstrator X achieves the following overall results after surveying the blind grid and open field (legacy) using the same system (results indicate the number of munitions detected divided by the number of munitions emplaced):

	Blind grid	Open field
P_d^{res}	100/100 = 1.0	8/10 = .80

P_d^{res}: BLIND GRID versus OPEN FIELD (legacy). Using the example data above to compare probabilities of detection in the response stage, all 100 munitions out of 100 emplaced munitions items were detected in the blind grid while 8 munitions out of 10 emplaced were detected in the open field. Fischer's test must be used since a 100 percent success rate occurs in the data. Fischer's test uses the four input values to calculate a test statistic of 0.0075 that is compared against the critical value of 0.05. Since the test statistic is less than the critical value, the smaller response stage detection rate (0.80) is considered to be significantly less at the 0.05 level of significance. While a significant result does not prove a cause-and-effect relationship exists between the change in survey area and degradation in performance, it does indicate that the detection ability of demonstrator X's system seems to have been degraded in the open field relative to results from the blind grid using the same system. This is an example of a one-sided Chi-squared test.

APPENDIX B. DAILY WEATHER LOGS

Date, 12	Time, EST	Average Temperature, °F	Total Precipitation, in.
26 Nov	0700	27.5	0.00
	0800	27.7	0.00
	0900	34.3	0.00
	1000	43.0	0.00
	1100	47.5	0.00
	1200	48.7	0.00
	1300	49.6	0.00
	1400	50.4	0.00
	1500	51.1	0.00
	1600	50.7	0.00
	1700	47.7	0.00
27 Nov	0700	38.5	0.06
	0800	38.1	0.02
	0900	37.8	0.00
	1000	38.3	0.01
	1100	38.5	0.08
	1200	38.3	0.06
	1300	37.0	0.02
	1400	36.9	0.01
	1500	37.0	0.01
	1600	37.6	0.00
	1700	37.4	0.00
28 Nov	0700	34.3	0.00
	0800	34.9	0.00
	0900	36.1	0.00
	1000	38.3	0.00
	1100	39.6	0.00
	1200	40.6	0.00
	1300	41.7	0.00
	1400	43.2	0.00
	1500	43.5	0.00
	1600	43.9	0.00
	1700	42.4	0.00
29 Nov	0700	25.5	0.00
	0800	28.2	0.00
	0900	33.4	0.00
	1000	38.3	0.00
	1100	43.2	0.00
	1200	45.1	0.00
	1300	46.8	0.00
	1400	47.1	0.00
	1500	47.5	0.00
	1600	46.9	0.00
	1700	45.0	0.00
30 Nov	0700	25.5	0.00
	0800	25.3	0.00
	0900	31.3	0.00
	1000	38.5	0.00
	1100	42.6	0.00
	1200	45.3	0.00
	1300	46.9	0.00
	1400	48.4	0.00
	1500	49.3	0.00
	1600	48.7	0.00
	1700	46.2	0.00

EST = Eastern Standard Time.

APPENDIX C. SOIL MOISTURE

Date: 26 November 2012 **Time:** 0700, 1700			
Probe Location	**Layer, in.**	**A.M. Reading, %**	**P.M. Reading, %**
Wet area	0 to 6	-	-
	6 to 12	-	-
	12 to 24	-	-
	24 to 36	-	-
	36 to 48	-	-
Wooded area	0 to 6	-	-
	6 to 12	-	-
	12 to 24	-	-
	24 to 36	-	-
	36 to 48	-	-
Open area	0 to 6	-	-
	6 to 12	-	-
	12 to 24	-	-
	24 to 36	-	-
	36 to 48	-	-
Calibration lanes	0 to 6	-	-
	6 to 12	-	-
	12 to 24	-	-
	24 to 36	-	-
	36 to 48	-	-
Blind grid/moguls	0 to 6	-	-
	6 to 12	-	-
	12 to 24	-	-
	24 to 36	-	-
	36 to 48	-	-

Date: 27 November 2012 **Time:** 0700, 1700			
Probe Location	**Layer, in.**	**A.M. Reading, %**	**P.M. Reading, %**
Wet area	0 to 6	-	-
	6 to 12	-	-
	12 to 24	-	-
	24 to 36	-	-
	36 to 48	-	-
Wooded area	0 to 6	-	-
	6 to 12	-	-
	12 to 24	-	-
	24 to 36	-	-
	36 to 48	-	-
Open area	0 to 6	-	-
	6 to 12	-	-
	12 to 24	-	-
	24 to 36	-	-
	36 to 48	-	-
Calibration lanes	0 to 6	-	-
	6 to 12	-	-
	12 to 24	-	-
	24 to 36	-	-
	36 to 48	-	-
Blind grid/moguls	0 to 6	-	-
	6 to 12	-	-
	12 to 24	-	-
	24 to 36	-	-
	36 to 48	-	-

Date: 28 November 2012 **Time:** 0700, 1700			
Probe Location	**Layer, in.**	**A.M. Reading, %**	**P.M. Reading, %**
Wet area	0 to 6	-	-
	6 to 12	-	-
	12 to 24	-	-
	24 to 36	-	-
	36 to 48	-	-
Wooded area	0 to 6	-	-
	6 to 12	-	-
	12 to 24	-	-
	24 to 36	-	-
	36 to 48	-	-
Open area	0 to 6	-	-
	6 to 12	-	-
	12 to 24	-	-
	24 to 36	-	-
	36 to 48	-	-
Calibration lanes	0 to 6	17.4	17.3
	6 to 12	25.4	25.6
	12 to 24	25.8	26.2
	24 to 36	30.7	30.7
	36 to 48	47.5	47.5
Blind grid/moguls	0 to 6	13.0	12.8
	6 to 12	23.4	23.3
	12 to 24	27.5	27.4
	24 to 36	28.7	28.6
	36 to 48	35.4	35.3

Date: 29 November 2012 **Time:** 0700, 1700			
Probe Location	**Layer, in.**	**A.M. Reading, %**	**P.M. Reading, %**
Wet area	0 to 6	-	-
	6 to 12	-	-
	12 to 24	-	-
	24 to 36	-	-
	36 to 48	-	-
Wooded area	0 to 6	-	-
	6 to 12	-	-
	12 to 24	-	-
	24 to 36	-	-
	36 to 48	-	-
Open area	0 to 6	-	-
	6 to 12	-	-
	12 to 24	-	-
	24 to 36	-	-
	36 to 48	-	-
Calibration lanes	0 to 6	17.2	17.1
	6 to 12	25.8	25.5
	12 to 24	26.1	26.0
	24 to 36	30.4	30.3
	36 to 48	47.4	47.2
Blind grid/moguls	0 to 6	12.7	12.6
	6 to 12	23.2	23.1
	12 to 24	27.4	27.3
	24 to 36	28.5	28.5
	36 to 48	35.2	35.4

Date: 30 November 2012 **Time:** 0700, 1700			
Probe Location	**Layer, in.**	**A.M. Reading, %**	**P.M. Reading, %**
Wet area	0 to 6	-	-
	6 to 12	-	-
	12 to 24	-	-
	24 to 36	-	-
	36 to 48	-	-
Wooded area	0 to 6	-	-
	6 to 12	-	-
	12 to 24	-	-
	24 to 36	-	-
	36 to 48	-	-
Open area	0 to 6	-	-
	6 to 12	-	-
	12 to 24	-	-
	24 to 36	-	-
	36 to 48	-	-
Calibration lanes	0 to 6	17.0	16.9
	6 to 12	25.4	25.3
	12 to 24	25.8	25.7
	24 to 36	30.1	30.0
	36 to 48	47.1	47.0
Blind grid/moguls	0 to 6	12.6	12.4
	6 to 12	23.0	22.8
	12 to 24	27.3	27.1
	24 to 36	28.4	28.4
	36 to 48	35.0	34.9

APPENDIX D. DAILY ACTIVITY LOGS

Date, 2012	No. of People	Area Tested	Status Start Time	Status Stop Time	Duration, min.	Operational Status	Operational Status Comments	Track Method	Pattern	Field Conditions	
26 November	5	Calibration Lanes	1430	1530	45	Initial set-up	Initial mobilization	GPS	Linear	Sunny	Cold
27 November	5	Calibration Lanes	830	1230	240	Initial set-up	Initial mobilization	GPS	Linear	Rainy	Cold
27 November	5	Calibration Lanes	1230	1340	70	Break/lunch	Break/lunch	GPS	Linear	Rainy	Cold
27 November	5	Calibration Lanes	1340	1425	45	Initial set-up	Initial mobilization	GPS	Linear	Rainy	Cold
28 November	5	Calibration Lanes	835	1120	165	Initial set-up	Initial mobilization	GPS	Linear	Sunny	Cold
28 November	5	Calibration Lanes	1120	1135	15	Calibration	Calibration	GPS	Linear	Sunny	Cold
28 November	5	Calibration Lanes	1135	1205	30	Collecting data	Collect data	GPS	Linear	Sunny	Cold
28 November	5	Blind Test Grid	1205	1215	10	Calibration	Calibration	GPS	Linear	Sunny	Cold
28 November	5	Blind Test Grid	1215	1310	55	Collecting data	Collect data	GPS	Linear	Sunny	Cold
28 November	5	Blind Test Grid	1310	1335	25	Break/lunch	Break/lunch	GPS	Linear	Sunny	Cold
28 November	5	Blind Test Grid	1335	1455	80	Collecting data	Collect data	GPS	Linear	Sunny	Cold
28 November	5	Blind Test Grid	1455	1545	50	Daily start, stop	Equipment breakdown	GPS	Linear	Sunny	Cold
30 November	4	Blind Test Grid	1120	1135	15	Daily start, stop	Set up equipment	GPS	Linear	Sunny	Cold
30 November	4	Blind Test Grid	1135	1150	15	Collecting data	Collect data	GPS	Linear	Sunny	Cold
30 November	4	Blind Test Grid	1150	1545	235	Demobilization	Demobilization	GPS	Linear	Sunny	Cold

APPENDIX E. REFERENCES

1. Standardized UXO Technology Demonstration Site Handbook, ATEC Project No. 8-CO-160-000-473, Report No. ATC-8349, March 2002.

2. Aberdeen Proving Ground Soil Survey Report, October 1998.

3. Data Summary, UXO Standardized Test Site: APG Soils Description, May 2002.

APPENDIX F. ABBREVIATIONS

APG = U.S. Army Aberdeen Proving Ground
ATC = U.S. Army Aberdeen Test Center
ATEC = U.S. Army Test and Evaluation Command
ATSS = U.S. ArmyAberdeen Test Support Services
BAR = background alarm rate
DGPS = Digital Global Positioning System
DMM = discarded military munitions
DOD = Department of Defense
DOE = Department of Energy
E = efficiency
EPA = Environmental Protection Agency
EQT = Environmental Quality Technology
ERDC = U.S. Army Corps of Engineers Engineering Research and Development Center
EST = Eastern Standard Time
ESTCP = Environmental Security Technology Certification Program
GT = ground truth
HEAT = high-explosive antitank
IDA = Institute for Defense Analysis
JPG = Jefferson Proving Ground
MM = military munitions
NS = nonstandard munition
P_{ba} = probability of background alarm
P_{cd} = probability of clutter detection
P_d = probability of detection
P_{fp} = probability of false positive
POC = point of contact
QA = quality assurance
QC = quality control
R_{ba} = background alarm rejection rate
R_{fp} = false positive rejection rate
R_{halo} = halo radius
ROC = receiver-operating characteristic
S = standard munition
SERDP = Strategic Environmental Research and Development Program
SL = Survivability/Lethality
TDSS = Threat Detection and Systems Survivability
USAEC = U.S. Army Environmental Command
UXO = unexploded ordnance
YPG = U.S. Army Yuma Proving Ground

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